ATTACHMENT S6C: EVALUATION OF ALTERNATIVES

1.0 DEFINITION OF RCRA REMEDIAL ALTERNATIVE EVALUATION STANDARDS AND OTHER FACTORS

The following paragraphs define the Resource Conservation and Recovery Act (RCRA) standards used to evaluate the corrective measure alternatives for Remediation Area (RA) 1 through RA 9.

1.1 Protect Human Health and the Environment

This standard addresses the degree to which an alternative is protective of human health and the environment considering both long-term and short-term remedies. Evaluation includes measures not directly related to cleanup, source control, or waste management (e.g., measures to prevent direct contact with waste management units or to provide an alternate drinking water supply).

1.2 Attain Cleanup Standards

This standard is defined as meeting the proposed Final Media Cleanup Levels (FMCLs) approved by the US Environmental Protection Agency (USEPA) and outlined in Section 2.0. Compliance with cleanup standards does not require removal or treatment of all contaminated material above specific constituent concentrations; remedies may attain cleanup standards through combinations of removal, treatment, and engineering and institutional controls. The evaluation will include an estimated time frame to meet the cleanup standards.

1.3 Control the Source of Releases

This standard addresses the extent to which ongoing sources of contamination have been controlled or eliminated to provide long-term effectiveness and protection of human health and the environment. The evaluation will include a discussion of the anticipated success of the remedy and track record of the technologies.

1.4 Comply with Applicable Standards for Management of Waste (With or Without Waivers)

Compliance with cleanup standards is defined by meeting the requirements of the RCRA Order and Model Toxics Control Act (MTCA) (Chapters 173-340 in the Washington Administrative Code [WAC]). Waste containing polychlorinated biphenyls (PCBs) and trichloroethene (TCE) will be managed to comply with Chapter 173-303-140 WAC Land Disposal Restrictions (LDR) regulations. Waivers such as contained-in determination (CID) or Toxic Substances Control Act (TSCA) Risk Based Determination Approval (RBDA) may be used to comply with waste management standards.

2.0 OTHER FACTORS

After the four evaluation standards described above are met, the following five general decision factors will be used to further evaluate technical measures and management controls.

2.1.1 Long-term Reliability and Effectiveness

This factor assesses risks remaining at the site after the remedial alternative has been implemented, the reliability of the alternative at reducing risks over an extended period of time,

and the certainty that the alternative will be successful at achieving the intended results. The evaluation of the alternatives will include the following:

- The effectiveness of the alternative under analogous site conditions.
- The potential impact resulting from a failure of the alternative, including failures from uncontrollable changes at the site (e.g., heavy rain storms, induced groundwater flow changes from off-site pumping wells.
- Estimates of the projected useful life (length of time the level of effectiveness can be maintained) of the overall alternative and of its component technologies.

2.1.2 Reduction in Toxicity, Mobility, or Volume of Waste

This factor addresses the extent an alternative is used to eliminate or substantially reduce the potential risk, and the extent to which the alternative could cause further releases or risks to human health or the environment. The evaluation will include a comparison of initial site conditions and anticipated post-cleanup conditions.

2.1.3 Short-term Effectiveness

This factor addresses short-term risks to site workers and the environment while the alternative is being implemented. These short-term risks include fire, explosion, exposure to hazardous waste, and risks from treatment, excavation, transportation, and containment of hazardous waste.

2.1.4 Implementability

This factor addresses the degree of difficulty in implementing each alternative. The implementability factor focuses on less quantifiable known and potential difficulties including the following:

- Administrative Activities – The permitting requirements, legal and/or regulatory constraints, coordination between agencies, and time to implement these activities.
- Constructability and Schedule – The ability to construct the alternative, time required to implement the alternative, and time required to achieve beneficial results.
- Availability of services and materials – The local availability of experienced contractors, personnel, equipment, materials, storage capacity, and disposal services required to implement the alternative.
- Availability of technologies – The availability of potential technologies for each alternative.

2.1.5 Cost

This factor is used to consider the relative costs of performing each alternative, including engineering, site preparation, construction, materials, labor, sampling and analysis, waste management and disposal, permitting, health and safety training, and operation and maintenance.

The relative cost estimates are based on the description of the alternatives and associated assumptions outlined in Section 6.0 and in Attachment S6D. The design assumptions are identified for the purposes of comparing the alternatives, but may not be the same assumptions used for the final, detailed design. Pre-design investigations will be included in the final design

phase for the recommended remedial actions and the results of these investigations could result in modifications to the preliminary designs presented in this Corrective Measures Study (CMS).

2.1.6 Restoration Time Frame

Restoration time frame was included in the evaluation process of the RCRA "other factors" to assure USEPA that the remedial alternatives would consider whether the recommended alternative would provide for a reasonable restoration time frame. Evaluation of restoration time frame was based on WAC 173-340-360, which requires specific factors be considered to determine whether a cleanup action provides a reasonable restoration time frame. Those factors include the following:

- Potential risks posed by the site to human health and the environment
- Practicability of a shorter restoration time frame
- Current and potential future use of the site, surrounding areas and associated resources that are or may be, affecting releases for the site
- Availability of alternative water supplies
- Likely effectiveness of institutional controls
- Ability to control and monitor migration of hazardous substances form the site
- Toxicity of hazardous substances at the site
- Natural processes that reduce concentration of hazardous substances and have been documented to occur at the site or under similar site conditions

Even when a remedial action is determined to provide a reasonable restoration time frame, it does not necessarily mean that the primary RCRA standards have been met.

3.0 ALTERNATIVE EVALUATION

Attachment S6C provides details of the remedial alternative evaluation process for each RA (RAs 1 through 9) subject to the process outlined in Section 6.5. The following text identifies how the remedial alternatives for each of the RAs meet the requirements of the four basic standards of the RCRA Alternative Evaluation Standards. In addition, the text provides technical justification and location specific factors that were considered during the scoring of each of the "other factors" that are part of the RCRA Alternative Evaluation Standards as well as the project-specific other factor "Restoration Time Frame." These ratings, as well as the total net benefit for each remedial alternative are summarized for each RA in Tables 6-1C through 6-9C. Cost estimates to support cost effectiveness scoring are provided in Attachment S6D.

3.1 RA 1: 2-10 North Sheetpile Area Remedial Alternative Evaluation

Because active soil and groundwater remediation was ongoing at RA 1 at the time this CMS Report was prepared, soil and groundwater conditions are in flux. However, there are sufficient current groundwater data for RA 1 to evaluate remedial alternatives without conducting a sampling event to establish current conditions.

Alternative 1: Corrective Action Not Required with Controls – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because the main area of impacted soil and groundwater is contained within the 2-10 North Sheetpile and covered by the building's concrete floor slab. In addition, ongoing soil and groundwater interim measures (IMs) performed in the 2-10 North Sheetpile have reduced chlorinated volatile organic compound (cVOC) concentrations by more than 99.9 percent.
- Attain FMCLs – Alternative 1 meets this standard because, at the greatly reduced contaminant concentrations achieved by the ongoing IM, FMCLs are likely to be attained through natural attenuation and degradation with time.
- Control the Source of the Releases – Alternative 1 meets this standard because the contaminant source is controlled by the 2-10 North Sheetpile and the building slab. This steel structure controls and contains impacted groundwater and prevents it from transporting contaminants downgradient to the point of compliance (POC). The building slab provides a barrier that prevents direct contact by site workers.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it will not be overly effective at attaining cleanup standards without further actions. However, the limited attenuation that occurs under natural conditions is considered to be reliable because it occurs without the need for outside input and effort.

- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because this alternative does not directly reduce the toxicity of the contaminants; however, mobility is limited by the presence of the 2-10 North Sheetpile.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is no short-term risk to human health or the environment under this remedial alternative.
- Implementability – Alternative 1 rates high (5) because it is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost Effectiveness – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 1. The estimated cost for Alternative 1 is approximately $36,000 over five years for shoreline well monitoring and reporting.
- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative 2: Enhanced Reductive Dechlorination – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2 meets this standard because the main area of impacted soil and groundwater is contained within the 2-10 North Sheetpile covered by the building's concrete floor slab. The impacted groundwater inside of the sheetpile will be remediated using enhanced reductive dechlorination (ERD) with limited risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections. Potential source material within vadose-zone soil will not be treated directly by ERD. However, the ongoing IM being performed inside of the 2-10 North Sheetpile included soil vapor extraction (SVE) to remediate vadose-zone soil during the first stage of the IM.
- Attain FMCLs – Alternative 2 meets this standard because ERD has been demonstrated to reduce cVOC concentrations within a relatively short time frame. Based on past experience at Plant 2, FMCLs will be attained in groundwater in a reasonable time frame using ERD.
- Control the Source of the Releases – Alternative 2 meets this standard because the contaminant source is partially controlled by the 2-10 North Sheetpile and implementation of ERD is anticipated to reduce cVOC concentrations to levels less than applicable FMCLs, which would not generate cVOC vapors at unacceptable concentrations or FMCL exceedances at the POC.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2 meets this standard because ERD is an in-situ remedial technology and no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2 rates medium high (4) because ERD uses enhanced naturally-occurring bacteria to destroy the cVOCs. These

bacteria will still be present and active in the subsurface after the active remediation work has been completed.

- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2 rates high (5) because ERD reduces both the toxicity and volume of the cVOCs and the mobility of the cVOCs and other constituents of concern (COCs) is significantly limited by the presence of the 2-10 North Sheetpile.
- Short-term Effectiveness – Alternative 2 rates medium high (4) because ERD is an in-situ remedial technology that will not generate wastes and therefore substantially reduces exposure of on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment.
- Implementability – Alternative 2 rates medium high (4) because ERD is readily implementable; minor effort would be required to assemble the necessary equipment and materials and obtain access to the existing ERD injection wells.
- Cost Effectiveness – Alternative 2 rates medium high (4) because it is the second lowest cost alternative for RA 1. The estimated cost to implement Alternative 2, ERD in RA 1 for five years is approximately $304,000.
- Restoration Time Frame – Alternative 2 rates medium high (4) because ERD has been demonstrated at Plant 2, and specifically in the 2-10 North Sheetpile, to significantly reduce cVOC concentrations within a reasonable time frame.

Alternative 2a: Enhanced Reductive Dechlorination with Excavation and Off-Site Disposal – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2a meets this standard because the main area of impacted soil and groundwater is contained within the 2-10 North Sheetpile and impacted soil within the sheetpile will be remediated using direct excavation and off-site disposal. The impacted groundwater inside of the sheetpile will be remediated using ERD with limited risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections. The ongoing IM being performed inside of the 2-10 North Sheetpile included SVE to remediate vadose-zone soil. If any potential vadose-zone source material remains at unacceptable concentrations it will be excavated and disposed of off-site prior to initiating ERD under Alternative 2a.
- Attain FMCLs – Alternative 2a meets this standard because the combination of source removal and ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame. Based on past experience with ERD at Plant 2, FMCLs will be attained in groundwater in a reasonable time frame using source removal and ERD.
- Control the Source of the Releases – Alternative 2a meets this standard because the contaminant source is partially controlled by the 2-10 North Sheetpile and excavation of vadose-zone source material will further reduce the potential for future releases. Implementation of ERD is anticipated to further reduce cVOC concentrations to levels less than applicable FMCLs; thus, cVOC vapors would not exceed FMCLs at the POC.

- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2a meets this standard because the generated waste (excavated soil) would probably be disposed of at a RCRA Subtitle D landfill under a CID from the Washington State Department of Ecology (Ecology), which provides for a conditional exemption from hazardous waste disposal requirements.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2a rates high (5) because it includes source removal followed by enhancing the naturally-occurring bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2a rates medium high (4) because ERD reduces both the toxicity and volume of the cVOCs; also, the mobility of the cVOCs and other COCs is significantly limited by the presence of the 2-10 North Sheetpile. The mobility of contaminants in excavated soil will be significantly limited by internment in a RCRA Subtitle D landfill. However, the excavated vadose-zone source material will not undergo remediation to reduce its toxicity or volume.
- Short-term Effectiveness – Alternative 2a rates medium (3) because there are minor potential risks to human health and the environment during excavation and transport of the source soil. ERD is an in-situ remedial technology that will not generate wastes or expose on-site personnel to impacted soil or groundwater. In addition, the nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients, none of which pose a potential threat to human health or the environment.
- Implementability – Alternative 2a rates medium low (2) because the overlying and currently active 2-10 Building significantly complicates excavation of vadose-zone soil in RA 1. The ERD portion of Alternative 2a is readily implementable with minor effort required to assemble the necessary equipment and materials and obtain access to the existing ERD injection wells.
- Cost Effectiveness – Alternative 2a rates medium (3) because it is one of the higher cost remedial alternatives for RA 1. The estimated cost to implement Alternative 2a at RA 1 for five years is approximately $380,000.
- Restoration Time Frame – Alternative 2a rates high (5) because removal of vadose-zone sources material and the closed concrete degreaser will likely reduce the restoration time frame relative to ERD without source removal (Alternative 2).

Alternative AM-1: Adaptive Management for Inorganics in Groundwater – Description and Scope of Work

Boeing anticipates that short-term and long-term shoreline monitoring results will demonstrate that exceedance areas containing inorganic COCs in RA 1 do not impact groundwater at concentrations greater than proposed FMCLs at the POC (see Figure 6-3A). Based on historical data from shoreline wells in RA 1, Boeing anticipates that arsenic and copper will not exceed their FMCLs at the POC.

Where Adaptive Management for inorganics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data

evaluation and corrective action technology determinations. The Adaptive Management process for inorganic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-12.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

Implementation of the proposed corrective measures is expected to achieve FMCLs for RA 1 exceedance areas; however, there might be some POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

3.2 RA 2: 2-10 South Sheetpile Remedial Alternative Evaluation

Because active soil and groundwater remediation is ongoing at RA 2 at the time this CMS Report was prepared, soil and groundwater conditions are changing. However, there are sufficient current groundwater data for RA 2 that remedial alternatives can be designed without the need for an initial sampling event to establish current conditions.

Alternative 1: Corrective Action Not Required (with Controls) – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because the main area of impacted soil and groundwater is contained within the 2-10 South Sheetpile and covered by the 2-10 Building concrete floor slab. In addition, ongoing soil and groundwater IMs performed in the 2-10 South Sheetpile have reduced cVOC concentrations by more than 99 percent.
- Attain FMCLs – Alternative 1 meets this standard because, at the greatly reduced contaminant concentrations achieved by the ongoing IM, FMCLs are likely to be attained through natural attenuation and degradation with time.
- Control the Source of the Releases – Alternative 1 meets this standard because the contaminant source is controlled by the 2-10 South Sheetpile. This steel structure controls and contains impacted groundwater and prevents it from transporting contaminants downgradient to the POC. There are no historical exceedances of cVOCs in samples from shoreline wells downgradient of the 2-10 South Sheetpile. The building floor slab provides a barrier from direct contact by site workers.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it will not be overly effective at attaining cleanup standards without further actions.

However, the 2-10 South Sheetpile has been effective at preventing releases to the POC; attenuation that occurs under natural conditions is considered to be reliable because it occurs without the need for outside input or effort.

- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because it does nothing to reduce the toxicity of the contaminants; however, mobility is limited by the presence of the 2-10 South Sheetpile.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is no short-term risk to human health or the environment under this remedial alternative.
- Implementability – Alternative 1 rates high (5) because it is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost Effectiveness – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 2. The estimated cost for Alternative 1 is approximately $36,000 over five years for shoreline well monitoring and reporting.
- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative 2: Enhanced Reductive Dechlorination – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2 meets this standard because the main area of impacted soil and groundwater is contained within the 2-10 South Sheetpile. The impacted groundwater inside of the sheetpile will be remediated using ERD with limited risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections. Potential source material within vadose-zone soil will not be treated directly by ERD. However, the ongoing IM being performed inside of the 2-10 South Sheetpile included SVE to remediate vadose-zone soil during the initial stages of the IM.
- Attain FMCLs – Alternative 2 meets this standard because ERD has been demonstrated to significantly reduce cVOC concentrations within a relatively short time frame. Based on past experience at Plant 2, FMCLs will be attained in groundwater in a reasonable time frame using ERD.
- Control the Source of the Releases – Alternative 2 meets this standard because the contaminant source is controlled by the 2-10 South Sheetpile and implementation of ERD is anticipated to reduce cVOC concentrations to levels less than the FMCL; thus, cVOC vapors would not exceed FMCLs at the POC.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2 meets this standard because ERD is an in-situ remedial technology and no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2 rates medium high (4) because ERD uses enhanced naturally-occurring bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2 rates high (5) because ERD reduces both the toxicity and volume of the cVOCs; also, the mobility of the cVOCs and other COCs is significantly limited by the presence of the 2-10 South Sheetpile.
- Short-term Effectiveness – Alternative 2 rates medium high (4) because ERD is an in-situ remedial technology that will not generate wastes and therefore substantially reduces the exposure of on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment.
- Implementability – Alternative 2 rates medium high (4) because ERD is readily implementable with minor effort required to assemble the necessary equipment and materials and obtain access to the existing ERD injection wells.
- Cost Effectiveness – Alternative 2 rates medium high (4) because it is the second lowest cost alternative for RA 2. The estimated cost to implement Alternative 2, ERD, in RA 2 for five years is approximately $304,000.
- Restoration Time Frame – Alternative 2 rates medium high (4) because ERD has been demonstrated at Plant 2, and specifically in the 2-10 South Sheetpile, to significantly reduce cVOC concentrations within a reasonable time frame.

Alternative 2a: Enhanced Reductive Dechlorination with Excavation and Off-Site Disposal – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2a meets this standard because the main area of impacted soil and groundwater is contained within the 2-10 South Sheetpile and impacted soil within the sheetpile will be remediated using direct excavation and off-site disposal. The impacted groundwater inside of the sheetpile will be remediated using ERD with limited risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections. The ongoing IM being performed inside of the 2-10 South sheetpile included SVE, which was performed in the early stages of the IM to remediate vadose-zone soil. If any potential vadose-zone source material remains at unacceptable concentrations, it will be excavated and disposed of off site prior to initiating ERD under Alternative 2a.
- Attain FMCLs – Alternative 2a meets this standard because the combination of source removal and ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame. Based on past experience with ERD at Plant 2, FMCLs will be attained in groundwater in a reasonable time frame using ERD.
- Control the Source of the Releases – Alternative 2a meets this standard because the contaminant source is partially controlled by the 2-10 South Sheetpile and excavation of vadose-zone source material will further reduce the potential for future releases. Implementation of ERD is anticipated to further reduce cVOC concentrations to levels

less than the FMCL, which would not generate cVOC vapors at unacceptable concentrations or FMCL exceedances at the POC.

- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2a meets this standard because the generated waste (excavated soil) would probably be disposed of at a RCRA Subtitle D landfill under a CID from Ecology, which provides for a conditional exemption from hazardous waste disposal requirements.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2a rates high (5) because it includes source removal followed by enhancing the naturally-occurring bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2a rates medium high (4) because ERD reduces both the toxicity and volume of the cVOCs and the mobility of the cVOCs and other COCs is significantly limited by the presence of the 2-10 South Sheetpile. The mobility of contaminants in excavated soil will be significantly limited by internment in a RCRA Subtitle D landfill. However, the excavated vadose-zone source material will not undergo remediation to reduce its toxicity or volume.
- Short-term Effectiveness – Alternative 2a rates medium (3) because there are minor potential risks to human health and the environment during excavation and transport of the source soil. ERD is an in-situ remedial technology that will not generate wastes or expose on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment.
- Implementability – Alternative 2a rates medium low (2) because the overlying and currently active 2-10 Building significantly complicates excavation of vadose-zone soil in RA 2. The ERD portion of Alternative 2a is readily implementable with minor effort required to assemble the necessary equipment and materials and obtain access to the existing ERD injection wells.
- Cost Effectiveness – Alternative 2a rates medium (3) because it is one of the higher cost remedial alternatives for RA 2. The estimated cost to implement Alternative 2a, ERD, in RA 2 for five years is approximately $338,000.
- Restoration Time Frame – Alternative 2a rates high (5) because removal of vadose-zone source material will likely reduce the restoration time frame relative to ERD without source removal (Alternative 2).

Alternative AM-1: Adaptive Management for Inorganics in Groundwater – Description and Scope of Work

Boeing anticipates that short-term and long-term shoreline monitoring results will demonstrate that exceedance areas containing inorganic COCs in RA 2 do not impact groundwater at concentrations greater than proposed FMCLs at the POC (see Figure 6-4A). Based on historical data from shoreline wells in RA 2, Boeing anticipates that arsenic and copper will not exceed their FMCLs at the POC. The nickel exceedance areas in RA 2 are not expected to exceed the FMCL using the current nickel analysis that reduces the effects of saline matrix interference.

Where Adaptive Management for inorganics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective action technology determinations. The Adaptive Management process for inorganic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-12.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

Implementation of the proposed corrective measures is expected to achieve FMCLs for RA 2 exceedance areas; however, there might be some POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

3.3 RA 3: 2-31 Area Remedial Alternative Evaluation

Soil and groundwater remediation actions (source excavation and ERD) were performed at RA 3 in association with the 2010-2012 Plant 2 Demolition/Redevelopment project. These remedial actions were conducted after the data gap investigation (DGI) for the 2-31 Area was completed. Remedial actions performed in the main area of cVOC impacted soil were excavation to the water table followed by the addition of the remediation substrate 3DMe™. The remediation substrate was added to the top of the water table prior to backfilling the excavation to promote ERD. As a result, soil and groundwater conditions in RA 3 are different than those presented in the 2-31 Area DGI, which was performed in 2009.

With the exception of Alternative 1, the changed soil and groundwater conditions in RA 3 require the performance of an initial soil and groundwater sampling event using a direct push probe rig to establish the current extent and concentrations of COCs in the RA 3 exceedance areas. Necessary adjustments to the scope and design of the selected remedial alternative will be made based on results of this initial sampling event.

Alternative 1: Corrective Action Not Required (with Controls) – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because high concentration cVOC impacted vadose-zone soil in RA 3 (the probable source of impacts to groundwater) was excavated and disposed of off site. In addition, the remediation substrate 3DMe™ was added to the bottom of the excavation prior to backfilling to promote geochemical conditions favorable for ERD in groundwater.
- Attain FMCLs – Alternative 1 meets this standard because, as noted above, the main area of cVOC impacted soil was excavated and 3DMe™ was added to the top of the water table prior to backfilling the excavation to promote ERD.

- Control the Source of the Releases – Alternative 1 meets this standard because the main cVOC contaminant source in vadose-zone soil was excavated. However, some residual impacted soil might remain outside of the limits of the excavation and this impacted soil could leach contaminants to groundwater.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated by this alternative.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it will not be overly effective at attaining cleanup standards without further actions. The rating would be lower if IMs had not been performed in RA 3. The main area of cVOC impacted soil was excavated and 3DMe™ was added to the top of the water table prior to backfilling the excavation to promote ERD. Geochemical conditions favorable for reductive dechlorination were noted during the DGI and are likely to be sustained in RA 3. This condition is considered to be reliable because it occurs without the need for outside input and effort.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because Alternative 1 by itself does not significantly reduce the toxicity, mobility, or volume of the contaminants. The volume of waste was reduced when the main area of impacted soil was excavated. In addition, naturally occurring attenuation will reduce the volume and concentrations of cVOCs, although it will likely be a slow process.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is no short-term risk to human health or the environment under this remedial alternative.
- Implementability – Alternative 1 rates high (5) because it is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost Effectiveness – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 3. The estimated cost for Alternative 1 is approximately $46,000 over five years for shoreline well monitoring and reporting.
- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative 2: Enhanced Reductive Dechlorination – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2 meets this standard because the main area of impacted soil and groundwater has already been excavated to groundwater and the remediation substrate 3DMe™ was placed in the excavation prior to backfilling to promote ERD. Implementation of additional ERD measures to attain FMCLs have only a minor risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections.

- Attain Cleanup FMCLs – Alternative 2 meets this standard because ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame. However, the anticipated time frame for ERD to attain cleanup standards is longer than for RA 1 and RA 2 because an initial sampling event must be performed before the ERD system can be designed and implemented at RA 3.
- Control the Source of the Releases – Alternative 2 meets this standard because the main contaminant source in vadose-zone soil was previously excavated at RA 3.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2 meets this standard because ERD is an in-situ remedial technology and no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2 rates medium high (4) because the RA 3 vadose-zone source material has been excavated and disposed of off site, which increases the effectiveness of ERD. ERD uses enhanced naturally-occurring bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2 rates high (5) because ERD reduces both the toxicity and volume of the cVOCs. However, the mobility of the cVOCs and other COCs is not limited by the presence of sheetpiles, as is the case at RA 1 and RA 2.
- Short-term Effectiveness – Alternative 2 rates medium high (4) because ERD is an in-situ remedial technology that will not generate wastes and therefore substantially reduces the exposure of on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment.
- Implementability – Alternative 2 rates medium high (4) because ERD is readily implementable; minor effort is required to drill injection and monitoring wells, assemble the necessary equipment and materials, and perform nutrient injections.
- Cost Effectiveness – Alternative 2 rates medium high (4) because it is the second lowest cost alternative for RA 3. The estimated cost to implement Alternative 2, ERD, in RA 3 for five years is approximately $311,000.
- Restoration Time Frame – Alternative 2 rates medium high (4) because the sources of cVOCs in vadose-zone soil were removed and 3DMe™ was added to the top of the water table prior to backfilling during a previous IM. These already completed remedial measures have likely created conditions favorable for further remedial actions using ERD.

Alternative 3: Air Sparging / Soil Vapor Extraction – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 3 meets this standard because the main area of impacted soil and groundwater has already been excavated. Any remaining impacted groundwater will be remediated using air sparging / soil vapor

extraction (AS/SVE) with limited risk of AS/SVE pushing contaminated groundwater or cVOC vapors into un-impacted areas or to receptors.

- Attain FMCLs – Alternative 3 meets this standard because AS/SVE has been demonstrated to significantly reduce cVOC concentrations within a short time frame similar sites.
- Control the Source of the Releases – Alternative 3 meets this standard because the main cVOC contaminant source in soil has been removed by excavation in RA 3. However, operation of an AS/SVE system could cause cVOC vapors to be released to the atmosphere if the off-gas treatment system were to fail.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 3 meets this standard because the waste (spent activated carbon) generated by Alternative 3 would probably be disposed of at a RCRA Subtitle D landfill under a CID from Ecology, which is a type of waiver.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 3 rates medium high (4) because AS/SVE systems, while generally reliable, have mechanical and electrical components that require maintenance and repair. In addition, AS/SVE is prone to rebound effects because permeable zones are preferentially remediated, temporarily giving the appearance of attaining cleanup goals and potentially leaving residual contaminant mass in less permeable zones.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 3 rates medium (3) because the proposed transect of AS/SVE wells is designed to strip volatiles from groundwater as it flows toward the waterway but does not remove volatiles throughout the exceedance area. In addition, AS/SVE only reduces the mobility of the cVOCs by transferring them to Granular Activated Carbon (GAC). The volume and toxicity of cVOCs is not reduced by AS/SVE, but is immobilized then removed from Plant 2 and transferred to an off-site disposal facility, probably a RCRA Subtitle D landfill. However, if the spent GAC is disposed of by incineration then the volume and toxicity of the cVOCs will be reduced.
- Short-term Effectiveness – Alternative 3 rates medium (3) because there are minor potential risks to human health and the environment resulting from installation, operation, and maintenance of the electrical and mechanical systems necessary to implement an AS/SVE remedy.
- Implementability – Alternative 3 rates medium (3) because, although there are no buildings causing access issues similar to those at RA 1 and RA 2, none of the wells, piping, or electrical systems required for AS/SVE are currently installed at RA 3.
- Cost Effectiveness – Alternative 3 rates medium (3) because it is the highest cost remedial alternative for RA 3. The estimated costs to install, implement, operate, monitor, and maintain an AS/SVE system at RA 3 is approximately $609,000.
- Remediation Time Frame – Alternative 3 rates medium high (4). FMCLs should be attainable within a reasonable time frame provided there is sufficient coverage by the system layout. However, remedial technologies such as AS/SVE that rely on physical stripping of cVOC from soil and groundwater reach a point of diminishing returns at

lower concentrations and will become less efficient as concentrations approach FMCLs.

Alternative AM-1: Adaptive Management for Inorganics in Groundwater – Description and Scope of Work

Boeing anticipates that short-term and long-term shoreline monitoring results will demonstrate that exceedance areas containing inorganic COCs in RA 3 do not impact groundwater at concentrations greater than proposed FMCLs at the POC. Based on historical data from shoreline well PL2-233A in RA 3, Boeing anticipates that arsenic, cadmium, copper, nickel, and zinc will not exceed their FMCLs at the POC.

Where Adaptive Management for inorganics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective action technology determinations. The Adaptive Management process for inorganic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-12.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

Implementation of the proposed corrective measures is expected to achieve FMCLs for RA 3 exceedance areas; however, there might be some POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

Alternative AM-3: Adaptive Management for PCBs in Groundwater – Description and Scope of Work

The potential for groundwater treatment technology and additional groundwater monitoring has been retained for PCBs, which have only been detected at the POC in samples from shoreline monitoring well PL2-621A, using the current analytical method. Boeing will continue to analyze for PCB Aroclors in groundwater at this location using USEPA Method 8082A with an MDL of approximately 0.01 µg/L and will compare those data to practical quantitation limits (PQL) of 0.1 µg/L. After completion of 8 semiannual monitoring events, Boeing may request an Adaptive Management response to the data collected from this well.

In the future, Boeing will conduct PCB analysis in groundwater using a high-sensitivity analytical method (e.g., USEPA Method 1668) to achieve a reporting limit equal to or lower than the Water Quality Standards (WQS), which is the TMCL for PCBs. At this time, USEPA may require sampling for PCBs at wells where PCB sampling had previously been discontinued. Boeing will work with USEPA through an Adaptive Management process to apply the high-sensitivity PCB analysis method for this ongoing groundwater monitoring, which may include specific requirements for data collection and analysis. As new data collected under this method become available, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and response.

3.4 RA 4: 2-66 Sheetpile Remedial Alternative Evaluation

Soil and groundwater remediation actions were performed at RA 4 in association with the 2010-2012 Plant 2 Demolition/Redevelopment project after the DGI for the 2-66 Area was completed. Additional soil source excavation was performed in RA 4 to install the duct bank and the stormwater swales and their associated piping and outfalls. Vadose-zone soil inside of the 2-66 Sheetpile was excavated and the remediation substrate 3DMe™ was added to the excavation to promote and maintain conditions favorable for ERD. In addition, the Southwest Bank was cut back and completed as habitat as part of the Duwamish Sediment Other Area (DSOA) project. As a result of this extensive work, soil and groundwater conditions in RA 4 are different than those presented in the 2-66 Area DGI, which was performed in 2006.

With the exception of Alternative 1, the changed soil and groundwater conditions in RA 4 require the performance of an initial pre-design soil and groundwater sampling event using a direct push probe rig to establish the current extent and concentrations of COCs in the RA 4 exceedance areas. Necessary adjustments to the scope and design of the selected remedial alternative will be made based on results of this initial sampling event.

The lack of current groundwater data also requires the inclusion of some assumptions, which are based on available data and professional judgment. In addition, for some of the remedial alternatives estimated values have been used to define the proposed scope of work that will be referenced for this evaluation. When applicable, estimated or assumed values are identified in the text.

Alternative 1: Corrective Action Not Required (with Controls) – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because the 2-66 Sheetpile, the main area of impacted soil and groundwater in RA 4, has undergone IMs; this main area has also been excavated to groundwater and the remediation substrate 3DMe™ was placed in the excavation prior to backfilling to continue ERD. In addition, a significant volume of vadose-zone soil was excavated and disposed of off site for duct bank and stormwater swale installation, and for Southwest Bank cutback. Implementation of additional ERD measures to attain FMCLs have only a minor risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections.
- Attain FMCLs – Alternative 1 meets this standard because the main area of cVOC impacted soil was excavated and 3DMe™ was added to the top of the water table prior to backfilling the 2-66 Sheetpile excavation to promote ERD.
- Control the Source of the Releases – Alternative 1 meets this standard because much of the cVOC contaminant source in vadose-zone soil inside and outside of the sheetpile was excavated and disposed of off site. However, some impacted soil remains outside of the limits of the excavations outside of the 2-66 Sheetpile and this impacted soil could leach contaminants to groundwater.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated by this alternative.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it will not be overly effective at attaining cleanup standards without further actions. The rating would be lower if IMs had not been performed in RA 4. Geochemical conditions favorable for reductive dechlorination are likely to persist for under natural conditions in RA 4 and this condition is considered to be reliable because it occurs without the need for outside input and effort.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because Alternative 1 by itself does not significantly reduce the toxicity, mobility, or volume of the contaminants. The volume of waste was reduced when the main area of impacted soil, the 2-66 Sheetpile, was excavated. A significant volume of vadose-zone soil was also excavated and disposed of off site for duct bank and stormwater swale installation, and for Southwest Bank cutback. In addition, naturally occurring attenuation will reduce the volume and concentrations of cVOCs.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is no short-term risk to human health or the environment under this remedial alternative.
- Implementability – Alternative 1 rates high (5) because it is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 4. The estimated cost for Alternative 1 is approximately $78,000 over a period of five years for costs associated with semiannual sampling and reporting for the six shoreline monitoring wells currently installed in RA 4.
- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative 2: Enhanced Reductive Dechlorination – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2 meets this standard because the 2-66 Sheetpile, the main area of impacted soil and groundwater in RA 4, has undergone IMs; this main area has also been excavated to groundwater and the remediation substrate 3DMe™ was placed in the excavation prior to backfilling to continue ERD. In addition, a significant volume of vadose-zone soil was excavated and disposed of off site for duct bank and stormwater swale installation, and for Southwest Bank cutback. Implementation of additional ERD measures to attain FMCLs have only a minor risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections.
- Attain FMCLs – Alternative 2 meets this standard because ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame.
- Control the Source of the Releases – Alternative 2 meets this standard because much of the contaminant source material was previously excavated and the sheetpile and asphalt pavement contain the remaining impacted media.

- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2 meets this standard because ERD is an in-situ remedial technology and no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2 rates medium high (4) because much of the RA 4 vadose-zone source material has been excavated and disposed of off site, which increases the effectiveness of ERD. ERD uses enhanced naturally-occurring bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2 rates high (5) because ERD reduces both the toxicity and volume of the cVOCs.
- Short-term Effectiveness – Alternative 2 rates medium high (4) because ERD is an in-situ remedial technology that will not generate wastes or expose on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment.
- Implementability – Alternative 2 rates medium high (4) because ERD is readily implementable with reasonable effort required to drill and develop the 15 injection wells, assemble the necessary equipment and materials, and perform nutrient injections.
- Cost Effectiveness – Alternative 2 rates medium high (4) because it is the second lowest cost alternative for RA 4. The estimated cost to implement Alternative 2, ERD in RA 4 for five years is approximately $542,000.
- Restoration Time Frame – Alternative 2 rates medium high (4) because the source of cVOCs in vadose-zone soil inside of the 2-66 Sheetpile were removed and 3DMe™ was added to the top of the water table prior to backfilling during a previous IM. These already completed remedial measures have likely created conditions favorable for further remedial actions using ERD.

Alternative 2a: Enhanced Reductive Dechlorination with Excavation and Off-Site Disposal – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2a meets this standard because the main area of impacted soil and groundwater is contained within the 2-66 Sheetpile and impacted vadose-zone soil within the sheetpile was excavated with off-site disposal. In addition, a significant volume of vadose-zone soil was excavated and disposed of off site for duct bank and stormwater swale installation, and for Southwest Bank cutback. Under Alternative 2a, cVOC impacted soil associated with Area of Concern (AOC) 2-66.53 (TCE Degreaser) would also be excavated with off-site disposal prior to initiating ERD.
- Attain FMCLs – Alternative 2a meets this standard because the combination of source removal and ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame.

- Control the Source of the Releases – Alternative 2a meets this standard because the contaminant source is partially controlled by the 2-66 Sheetpile and excavation of AOC 2-66.53 vadose-zone source material will further reduce the potential for future releases. Implementation of ERD is anticipated to further reduce cVOC concentrations to levels less than the FMCL; thus, cVOC vapors would not exceed FMCLs at the POC.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2a meets this standard because the generated waste (excavated soil) would probably be disposed of at a RCRA Subtitle D landfill under a CID from Ecology.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2a rates high (5) because Alternative 2a includes source removal followed by enhancing the naturally-occurring bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2a rates medium high (4) because ERD reduces both the toxicity and volume of the cVOCs and the mobility of the cVOCs and other COCs is significantly limited by the presence of the 2-66 Sheetpile. The mobility of contaminants in excavated soil will be significantly limited by internment in a RCRA Subtitle D landfill. However, the excavated vadose-zone source material will not undergo remediation to reduce its toxicity or volume.
- Short-term Effectiveness – Alternative 2a rates medium (3) because there are minor potential risks to human health and the environment during excavation and transport of the source soil. ERD is an in-situ remedial technology that will not generate wastes or expose on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment.
- Implementability – Alternative 2a rates medium high (4) because there are no buildings that would complicate source excavation efforts in RA 4. The stormwater swale in the northwest corner of RA 4 is not anticipated to prevent source excavation. The ERD portion of Alternative 2a is readily implementable with minor effort required to drill and develop the 15 injection wells, assemble the necessary equipment and materials, and perform nutrient injections.
- Cost Effectiveness – Alternative 2a rates medium (3) because it is one of the higher cost remedial alternatives for RA 4. The estimated cost to implement Alternative 2a, ERD with excavation in RA 4 for five years is approximately $741,000.
- Restoration Time Frame – Alternative 2a rates high (5) because removal of vadose-zone source material will likely reduce the restoration time frame relative to ERD without source removal (Alternative 2).

Alternative 3: Air Sparging / Soil Vapor Extraction – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 3 meets this standard because the 2-66 Sheetpile, the main area of impacted soil and groundwater in RA 4, has undergone IMs and has also been excavated to groundwater and the remediation substrate 3DMe™ was placed in the excavation prior to backfilling to continue ERD. In addition, a significant volume of vadose-zone soil was excavated and disposed of off site for duct bank and stormwater swale installation, and for Southwest Bank cutback. Any remaining impacted groundwater will be remediated using AS/SVE with limited risk of AS/SVE pushing contaminated groundwater or cVOC vapors into un-impacted areas or to receptors.
- Attain FMCLs – Alternative 3 meets this standard because AS/SVE has been demonstrated to significantly reduce cVOC concentrations within a short time frame at similar sites. Attaining FMCLs might require a relatively long time frame because remedial technologies that rely on physical stripping of cVOCs from soil and groundwater reach a point of diminishing returns at lower concentrations and will become less efficient as cVOC concentrations approach FMCLs.
- Control the Source of the Releases – Alternative 3 meets this standard because the main cVOC contaminant source in soil has been removed by excavation.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 3 meets this standard because the waste (spent activated carbon) generated by Alternative 3 would probably be disposed of at a RCRA Subtitle D landfill under a CID from Ecology, which is a type of waiver.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 3 rates medium (3) because AS/SVE systems, while generally reliable, have mechanical and electrical components that require maintenance and repair. The presence of granular backfill in the duct bank line, which crosses RA 4, could potentially cause preferential pathway issues for the SVE system, limiting its effectiveness. In addition, AS/SVE is prone to rebound effects because permeable zones are preferentially remediated temporarily giving the appearance of attaining cleanup goals and potentially leaving residual contaminant mass in less permeable zones.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 3 rates medium (3) because the transect of AS/SVE wells is designed to strip volatiles from groundwater as it flows toward the waterway but does not remove volatiles throughout the exceedance area. AS/SVE reduces the mobility of the cVOCs by transferring them to GAC. The volume and toxicity of cVOCs is not reduced by AS/SVE, but is immobilized then removed from Plant 2 and transferred to an off-site disposal facility, probably a RCRA Subtitle D landfill. If the spent GAC is disposed of by incineration then the volume and toxicity of the cVOCs will be reduced.
- Short-term Effectiveness – Alternative 3 rates medium high (4) because there are minor potential risks to human health and the environment resulting from installation, operation, and maintenance of the electrical and mechanical systems necessary to implement an AS/SVE remedy.
- Implementability – Alternative 3 rates medium (3) because, although there are no overlying buildings that create access issues similar to those at RA 1 and RA 2, none

of the wells, piping, or electrical systems required for AS/SVE are currently installed at RA 4. This alternative requires installation of an assumed 10 AS wells and 20 SVE wells plus trenching, piping, and controls to connect the AS and SVE wells to the equipment trailers.

- Cost Effectiveness – Alternative 3 rates medium (3) because it is the highest cost remedial alternative for RA 4. The estimated cost to install, implement, operate, monitor, and maintain an AS/SVE system at RA 4 is approximately $880,000.
- Restoration Time Frame – Alternative 3 rates medium high (4) because attaining FMCLs might require a relatively long restoration time frame. Remedial technologies that rely on physical stripping of cVOC from soil and groundwater reach a point of diminishing returns at lower concentrations and will become less efficient as concentrations approach FMCLs.

Alternative 3a: Air Sparging / Soil Vapor Extraction with Excavation and Off-Site Disposal – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 3a meets this standard because the 2-66 Sheetpile, the main area of impacted soil and groundwater in RA 4, has undergone IMs and has also been excavated to groundwater and the remediation substrate 3DMe™ was placed in the excavation prior to backfilling to continue ERD. In addition, a significant volume of vadose-zone soil was excavated and disposed of off site for duct bank and stormwater swale installation, and for Southwest Bank cutback. Under Alternative 3a cVOC impacted soil associated with AOC 2-66.53 (TCE Degreaser) would also be excavated with off-site disposal prior to initiating ERD under Alternative 3a. Any remaining impacted groundwater will be remediated using AS/SVE with limited risk of AS/SVE pushing contaminated groundwater or cVOC vapors into un-impacted areas or to receptors.
- Attain FMCLs – Alternative 3a meets this standard because AS/SVE has been demonstrated to significantly reduce cVOC concentrations within a short time frame at similar sites. Attaining FMCLs might require a relatively long time frame because remedial technologies that rely on physical stripping of cVOC from soil and groundwater reach a point of diminishing returns at lower concentrations and will become less efficient as cVOC concentrations approach FMCLs.
- Control the Source of the Releases – Alternative 3a meets this standard because the main cVOC contaminant source in soil inside of the 2-66 Sheetpile was removed by excavation and a lesser cVOC source at AOC 2-66.53 will be removed by this remedial alternative.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 3a meets this standard because the waste (spent activated carbon) generated by Alternative 3a would probably be disposed of at a RCRA Subtitle D landfill CID from Ecology, which is a type of waiver.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 3a rates medium high (4) because AS/SVE systems, while generally reliable, have mechanical and electrical

components that require maintenance and repair. The presence of granular backfill in the duct bank line, which crosses RA 4, could potentially cause preferential pathway issues for the SVE system limiting its effectiveness. In addition, AS/SVE is prone to rebound effects because permeable zones are preferentially remediated temporarily giving the appearance of attaining cleanup goals and potentially leaving residual contaminant mass in less permeable zones. However, the additional source excavation performed as part of Alternative 3a should increase both long-term reliability and effectiveness.

- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 3a rates medium (3) because the volume and toxicity of contaminants in the excavated soil will not be reduced by excavation but rather transferred to a landfill where their mobility will be reduced. In addition, the proposed transect of AS/SVE wells is designed to strip volatiles from groundwater as it flows toward the waterway but does not remove volatiles throughout the exceedance area. AS/SVE reduces the mobility of the cVOCs by transferring them to GAC. The volume and toxicity of cVOCs is not reduced by AS/SVE, but is immobilized then removed from Plant 2 and transferred to an off-site disposal facility, probably a RCRA Subtitle D landfill. If the spent GAC is disposed of by incineration then the volume and toxicity of the cVOCs will be reduced.
- Short-term Effectiveness – Alternative 3a rates medium (3) because there are potential risks to human health and the environment associated with excavation and transportation of contaminated soil plus the risks resulting from installation, operation, and maintenance of the electrical and mechanical systems necessary to implement an AS/SVE remedy.
- Implementability – Alternative 3a rates medium (3) because, although there are no overlying buildings that create access issues similar to those at RA 1 and RA 2, none of the wells, piping, or electrical systems required for AS/SVE are currently installed at RA 4. This alternative requires installation of an assumed 10 AS wells and 20 SVE wells plus trenching, piping, and controls to connect the AS and SVE wells to the equipment trailers.
- Cost Effectiveness – Alternative 3a rates medium low (2) because it is the highest cost remedial alternative for RA 4. The estimated cost to install, implement, operate, monitor, and maintain an AS/SVE system at RA 4 is approximately $880,000. Soil excavation and disposal for Alternative 3a is an additional $1,078,000.
- Restoration Time Frame – Alternative 3a rates medium high (4) because attaining FMCLs might require a relatively long restoration time frame. Remedial technologies that rely on physical stripping of cVOC from soil and groundwater reach a point of diminishing returns at lower concentrations and will become less efficient as concentrations approach FMCLs.

Alternative AM-1: Adaptive Management for Inorganics in Groundwater – Description and Scope of Work

Boeing anticipates that short-term and long-term shoreline monitoring results will demonstrate that exceedance areas containing inorganic COCs in RA 4 do not impact groundwater at concentrations greater than proposed FMCLs at the POC.

Where Adaptive Management for inorganics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective action technology determinations. The Adaptive Management process for inorganic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-12.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

Implementation of the proposed corrective measures is expected to achieve FMCLs for RA 4 exceedance areas; however, there might be some POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

Alternative AM-3: Adaptive Management for PCBs in Groundwater – Description and Scope of Work

The potential for groundwater treatment technology and additional groundwater monitoring has been retained for PCBs, which have only been detected at the POC in samples from shoreline monitoring well PL2-621A, using the current analytical method. Boeing will continue to analyze for PCB Aroclors in groundwater at this location using USEPA Method 8082A with an MDL of approximately 0.01 µg/L and will compare those data to PQL of 0.1 µg/L. After completion of 8 semiannual monitoring events, Boeing may request an Adaptive Management response to the data collected from this well.

In the future, Boeing will conduct PCB analysis in groundwater using a high-sensitivity analytical method (e.g., USEPA Method 1668) to achieve a reporting limit equal to or lower than the WQS, which is the TMCL for PCBs. At this time, USEPA may require sampling for PCBs at wells where PCB sampling had previously been discontinued. Boeing will work with USEPA through an Adaptive Management process to apply the high-sensitivity PCB analysis method for this ongoing groundwater monitoring, which may include specific requirements for data collection and analysis. As new data collected under this method become available, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and response.

3.5 RA 5: South Yard Area Remedial Alternative Evaluation

Six soil sample locations exceed the FMCL for motor oil range petroleum hydrocarbons (MoRPH) and one soil sample location exceeds the FMCL for PCBs in the South Yard between 0.5 and 5 feet below ground surface (bgs). Based on South Yard Area DGI in 2005, the concentrations of cVOCs and other COCs in RA 5 were relatively low and cover a relatively large area. The distribution of cVOC breakdown products throughout RA 5, specifically vinyl chloride, indicates that reductive dechlorination of cVOCs is occurring in groundwater within this remediation area. It is likely that the extent and concentrations of cVOC exceedance areas have changed since 2005. As a result, soil and groundwater conditions in RA 5 are different than those presented in the South Yard Area DGI.

With the exception of Alternative 1, the changed soil and groundwater conditions in RA 5 require the performance of an initial soil and groundwater sampling event using a direct push probe rig to establish the current extent and concentrations of COCs in the RA 5 exceedance areas. Necessary adjustments to the scope and design of the selected remedial alternative will be made based on results of this initial sampling event.

Alternative 1: Corrective Action Not Required (with Controls) – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because based on DGI data, impacted groundwater in RA 5 does not reach the POC at the Duwamish Waterway with COCs at concentrations greater than their applicable FMCLs. Soil and groundwater exceedance areas in RA 5 are covered by pavement or buildings, significantly limiting the potential for exposure to human or environmental receptors.
- Attain FMCLs – Alternative 1 meets this standard because the main source of cVOC impacts, the former cisterns, were removed and excavated prior to the South Yard Area DGI. The relatively low cVOC concentrations in exceedance areas cVOC-1 and cVOC-2 are likely due to removal of these sources and natural attenuation.
- Control the Source of the Releases – Alternative 1 meets this standard because much of the cVOC contaminant source in vadose-zone soil was excavated and disposed of off site during cistern removal. However, small areas of soil with petroleum hydrocarbons at concentrations greater than direct contact cleanup levels remain at RA 5. These impacted soil areas potentially serve as an ongoing source of releases to groundwater.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated by this alternative.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it will not be overly effective at attaining cleanup standards without further actions. However, historical source removal at the cisterns significantly improved groundwater quality relative to historical conditions. DGI data demonstrate that cVOCs are dechlorinating under the reducing geochemical conditions in RA 5. The reducing geochemical conditions are likely to persist in RA 5 and this component of naturally attenuation is considered to be reliable because it occurs without the need for outside input and effort.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because this alternative by itself does not significantly reduce the toxicity, mobility, or volume of the contaminants. However, naturally occurring reductive dechlorination of cVOCs and natural attenuation of benzene, toluene, ethylbenzene, and xylene (BTEX) and petroleum hydrocarbon COCs will reduce the volume and concentrations, although it will likely be a slow process.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is almost no short-term risk to human health or the environment under this remedial alternative.

- Implementability – Alternative 1 rates high (5) because it is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost Effectiveness – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 5. The estimated cost for Alternative 1 is approximately $115,000 over a period of five years for costs associated with semiannual sampling and reporting for the nine property boundary monitoring wells currently installed in RA 5.
- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative 2: Enhanced Reductive Dechlorination – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2 meets this standard because the COC exceedance areas in RA 5 do not extend to the POC so there is a low risk of exposure. Implementation of ERD does not increase the already low potential for exposure and is anticipated to reduce the size and concentration of the cVOC exceedance areas in RA 5. Implementation of additional ERD measures to attain FMCLs have only a minor risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections.
- Attain FMCLs – Alternative 2 meets this standard because ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame. However, the anticipated time frame for ERD to attain cleanup standards is longer than for RA 1 and RA 2 because an initial pre-design sampling event to determine current conditions must be performed before the ERD system can be designed and implemented at RA 5. In addition, ERD implemented alone will not remediate the BTEX and petroleum hydrocarbon exceedance areas in RA 5.
- Control the Source of the Releases – Alternative 2 meets this standard because the main cVOC contaminant source at the former cisterns was previously excavated and the exceedance areas, based on DGI data, do not extent to the POC.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2 meets this standard because ERD is an in-situ remedial technology and no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2 rates medium (3) because the RA 5 vadose-zone cVOC source material in the cistern area has been excavated and disposed of off site, which increases the effectiveness of ERD. ERD enhances populations of naturally-occurring bacteria to destroy the cVOCs and these bacteria will still be present and active in the subsurface after the active remediation work has been completed. However, BTEX and petroleum hydrocarbon exceedance areas in RA 5 will not be remediated by ERD alone.

- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2 rates medium high (4) because ERD reduces both the toxicity and volume of the cVOCs. However, the mobility of the cVOCs and other COCs is not limited by the presence of sheetpiles as is the case at RA 1 and RA 2. In addition, the small BTEX and petroleum hydrocarbon exceedance areas in RA 5 will not be remediated by ERD alone.
- Short-term Effectiveness – Alternative 2 rates high (5) because ERD is an in-situ remedial technology that will not generate wastes or expose on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment.
- Implementability – Alternative 2 rates medium high (4) because ERD is readily implementable with reasonable effort required to drill and develop the assumed 10 A-Level and four B-Level injection wells, assemble the necessary equipment and materials, and perform nutrient injections.
- Cost Effectiveness – Alternative 2 rates medium high (4) because it is the second lowest cost alternative for RA 5. The estimated cost to implement Alternative 2, ERD, in RA 5 for five years is approximately $571,000.
- Restoration Time Frame – Alternative 2 rates medium high (4) because ERD has been demonstrated at Plant 2 to significantly reduce cVOC concentrations within a reasonable time frame.

Alternative 2a: Enhanced Reductive Dechlorination and Source Excavation – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2a meets this standard because the COC exceedance areas in RA 5 do not extend to the POC so there is a low risk of exposure. Implementation of source excavation and ERD does not increase the already low potential for exposure and is anticipated to reduce the size and concentration of the cVOC, BTEX, and petroleum hydrocarbon exceedance areas in RA 5. Implementation of additional ERD measures to attain FMCLs have only a minor risk of pushing contaminated groundwater into un-impacted areas or to receptors during nutrient injections. Excavation of the BTEX and petroleum hydrocarbon sources will remove the main source material but is not intended to remove all of the residual concentrations of those COCs.
- Attain FMCLs – Alternative 2a meets this standard because ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame. Based on past experience with ERD at Plant 2, FMCLs will be attained in groundwater in a reasonable time frame using ERD. The source removal actions proposed for BTEX and petroleum hydrocarbon exceedance areas in RA 5 will remove the main source material but residual impacts will be left in soil and groundwater. Residual concentrations of BTEX and petroleum hydrocarbons are anticipated to naturally degrade within a reasonable time frame based on experience with these compounds at Plant 2.
- Control the Source of the Releases – Alternative 2a meets this standard because the main cVOC contaminant source was previously excavated and the exceedance areas

based on DGI data do not extent to the POC. Alternative 2a also proposes source excavation for the BTEX and petroleum hydrocarbon exceedance areas in RA 5, which will further control the source of the releases in RA 5.

- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2a meets this standard because the generated waste (excavated soil) would probably be disposed of at a RCRA Subtitle D landfill under a CID from Ecology, which is a type of waiver.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2a rates high (5) because Alternative 2a includes source removal for BTEX and petroleum hydrocarbons combined with ERD to enhance the naturally-occurring anaerobic bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed, which increases the reliability and effectiveness of the remedial alternative.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2a rates medium high (4) because ERD reduces both the toxicity and volume of the cVOCs and the mobility of the cVOCs. The mobility of the BTEX and petroleum hydrocarbon contaminants in excavated soil will be significantly limited by internment in a landfill. The excavated vadose-zone source material will not undergo active remediation to reduce its toxicity or volume but will naturally degrade.
- Short-term Effectiveness – Alternative 2a rates medium high (4) because there are minor potential risks to human health and the environment during excavation and transport of the source soil. ERD is an in-situ remedial technology that will not generate wastes or expose on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment.
- Implementability – Alternative 2a rates medium high (4) because the BTEX and petroleum hydrocarbon exceedance areas are at locations that are readily accessible to standard excavation equipment. The ERD portion of Alternative 2a is implementable with some effort required to drill new injection wells, assemble the necessary equipment and materials, and perform and monitor the ERD injections.
- Cost Effectiveness – Alternative 2a rates medium (3) because it is one of the higher cost remedial alternatives for RA 5. The estimated cost to implement Alternative 2a, ERD with source excavation, in RA 5 for five years is approximately $670,000.
- Restoration Time Frame – Alternative 2a rates high (5) because removal of vadose-zone source material will likely reduce the restoration time frame relative to ERD without source removal (Alternative 2).

Alternative 2b: Enhanced Reductive Dechlorination and Enhanced Aerobic Degradation – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2b meets this standard because the COC exceedance areas in RA 5 do not extend to the POC so there is a

low risk of exposure. Implementation of ERD for cVOCs followed by enhanced aerobic degradation (EAD) for BTEX and petroleum hydrocarbons does not increase the already low potential for exposure and is anticipated to reduce the size and concentration of the cVOC, BTEX, and petroleum hydrocarbon exceedance areas in RA 5. Remediation substrate injections performed for ERD and EAD have only a minor risk of pushing contaminated groundwater into un-impacted areas or to receptors during those injections.

- Attain FMCLs – Alternative 2b meets this standard because ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame based on past experience with remedial actions using ERD (multiple locations) and EAD (at Other Area [OA] 9) at Plant 2.
- Control the Source of the Releases – Alternative 2b meets this standard because the main contaminant source was previously excavated and the exceedance areas, based on DGI data, do not extent to the POC. The BTEX and petroleum hydrocarbon source areas will not be excavated under this alternative but will be remediated using EAD after the ERD portion of the alternative is completed, assumed to be within five years.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2b meets this standard because ERD and EAD are in-situ remedial technologies and no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2b rates high (5) because the RA 5 vadose-zone source material in the cistern area has been excavated and disposed of off site, which increases the effectiveness of ERD. ERD uses enhanced naturally-occurring bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed. In addition, BTEX and petroleum hydrocarbon exceedance areas in RA 5 will be remediated by EAD following completion of the ERD portion of the alternative. Both technologies are considered effective and reliable for the conditions present in RA 5.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2b rates high (5) because ERD reduces both the toxicity and volume of the cVOCs and EAD reduces both the toxicity and volume of BTEX and petroleum hydrocarbons. The mobility of the COCs in RA 5 is not limited by the presence of sheetpiles as is the case at RA 1 and RA 2, but the RA 5 exceedance areas are stable or shrinking relative to historical data, indicating limited mobility.
- Short-term Effectiveness – Alternative 2b rates medium high (4) because ERD and EAD are in-situ remedial technologies that will not generate wastes or expose on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment. The EAD remediation substrate is non-toxic and does not pose a threat to human health or the environment.
- Implementability – Alternative 2b rates medium (3) because ERD is readily implementable with minor effort required to drill and develop the assumed 10 A-Level and four B-Level injection wells, assemble the necessary equipment and materials, and perform nutrient injections. EAD is also readily implementable using a direct push probe rig to inject the remediation substrate into the A-Level of the aquifer. Because

ERD and EAD are incompatible remedial technologies they cannot be implemented concurrently at the same location and the BTEX and petroleum hydrocarbon exceedance areas are within the footprint of the larger cVOC-1 exceedance area.

- Cost Effectiveness – Alternative 2b rates medium (3) because it is one of the higher cost alternatives for RA 5. The estimated cost to implement Alternative 2b, ERD followed by EAD in RA 5 for five years is approximately $691,000.
- Restoration Time Frame – Alternative 2b rates medium high (4). Both remedial technologies have been demonstrated to have good restoration time frames when implemented at Plant 2. However, ERD is incompatible with EAD and as a result, the EAD remedy will not be implemented until ERD is completed, which is assumed to be within five years of ERD initiation. EAD is assumed to require an additional three to five years to remediate BTEX and petroleum hydrocarbon exceedance areas in RA 5 to FMCLs.

Alternative 2c: Enhanced Reductive Dechlorination, Enhanced Aerobic Degradation, and Source Removal – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2c meets this standard because the COC exceedance areas in RA 5 do not extend to the POC so there is a low risk of exposure. Source removal followed by implementation of ERD for cVOCs, and then implementation of EAD for BTEX and petroleum hydrocarbons does not increase the already low potential for exposure. This alternative is anticipated to reduce the size and concentration of the cVOC, BTEX, and petroleum hydrocarbon exceedance areas in RA 5. Remediation substrate injections performed for ERD and EAD have only a minor risk of pushing contaminated groundwater into un-impacted areas or to receptors during those injections.
- Attain FMCLs – Alternative 2c meets this standard because ERD has been demonstrated to significantly reduce cVOC concentrations within a short time frame based on past experience with ERD at Plant 2. In addition, source removal followed by EAD in BTEX and petroleum hydrocarbon exceedance areas will quickly attain cleanup standards for soil and likely groundwater.
- Control the Source of the Releases – Alternative 2c meets this standard because the main cVOC contaminant source was previously excavated and the exceedance areas based on DGI data do not extent to the POC. Source material in the BTEX and petroleum hydrocarbon exceedance areas will be excavated under this alternative. Residual impacts will be remediated using ERD for cVOCs followed by EAD for BTEX and petroleum hydrocarbons, if needed.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2c meets this standard because the source removal portion of the alternative will generate petroleum hydrocarbon impacted soil that might also contain cVOCs. The ERD and EAD portions of this alternative are in-situ remedial technologies that will not generate wastes.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2c rates high (5) because the RA 5 vadose-zone source material in the cistern area has been excavated and disposed of off site, which increases the effectiveness of ERD. ERD uses enhanced naturally-occurring bacteria to destroy the cVOCs. These bacteria will still be present and active in the subsurface after the active remediation work has been completed. BTEX and petroleum hydrocarbon exceedance areas in RA 5 will be remediated by source removal followed by EAD. Implementation of EAD will be delayed until ERD is completed and might not be warranted if source removal and natural attenuation are sufficient to achieve FMCLs. The combination of these technologies is considered effective and reliable for the conditions present in RA 5.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2c rates high (5) because ERD reduces both the toxicity and volume of the cVOCs and EAD reduces both the toxicity and volume of BTEX and petroleum hydrocarbons. In addition, the RA 5 exceedance areas are stable or shrinking relative to historical data, indicating limited mobility. However, the toxicity and volume of contaminants in the vadose-zone soil excavated for source removal soil will be unchanged.
- Short-term Effectiveness – Alternative 2c rates medium (3) because there are potential risks to human health and the environment during excavation and transport of the source soil. ERD and EAD are in-situ remedial technologies that will not generate wastes or expose on-site personnel to impacted soil or groundwater. The nutrient substrate that is used to promote ERD is a mixture of food-grade ingredients that do not pose a potential threat to human health or the environment. The EAD remediation substrate is non-toxic and does not pose a threat to human health or the environment.
- Implementability – Alternative 2c rates medium (3) because ERD is readily implementable with minor effort required to drill and develop the assumed 10 A-Level and four B-Level injection wells, assemble the necessary equipment and materials, and perform nutrient injections. EAD is also readily implementable using a direct push probe rig to inject the remediation substrate into the A-Level of the aquifer. However, because ERD and EAD are incompatible remedial technologies they cannot be implemented concurrently at the same location and the BTEX and petroleum hydrocarbon exceedance areas are within the footprint of the larger cVOC exceedance area cVOC-1.
- Cost Effectiveness – Alternative 2c rates medium low (2) because it is the highest cost alternative for RA 5. The estimated cost to implement Alternative 2c, ERD, EAD, and source removal in RA 5 for five years is approximately $791,000.
- Restoration Time Frame – Alternative 2c rates high (5) because both ERD and EAD have been demonstrated to have good restoration time frames when implemented at Plant 2. ERD is incompatible with EAD and as a result, the EAD remedy will not be implemented until ERD is completed, which is assumed to be within five years of ERD initiation. However, source removal itself might be sufficient to achieve cleanup standards for BTEX and petroleum hydrocarbons, which would reduce the restoration time frame significantly. For cost estimation and rating purposes, EAD is assumed to be warranted following excavation. The estimate also assumes an additional three to five years of EAD remediation for BTEX and petroleum hydrocarbon exceedance areas in RA 5.

Alternative AM-1: Adaptive Management for Inorganics in Groundwater – Description and Scope of Work

Boeing anticipates that implementation of remedial actions for cVOC, BTEX, and petroleum hydrocarbon exceedance areas will reduce inorganic COC concentrations in RA 5. Boeing also anticipates that property boundary monitoring results will demonstrate that inorganic COCs in RA 5 do not impact groundwater at concentrations greater than FMCLs at the property boundary or the POC.

Where Adaptive Management for inorganics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective action technology determinations. The Adaptive Management process for inorganic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-12.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

Implementation of the proposed corrective measures is expected to achieve FMCLs for RA 5 exceedance areas; however, there might be some property boundary or POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

3.6 RA 6: OA 18 Area Remedial Alternative Evaluation

The RCRA Unit OA 18 (Building 2-40 East Parking Lot Area) is based on observations of staining and odor in fill material identified during the RCRA facility investigation (RFI) and DGI. Historical photos from the 1940s indicate that this area was used as an airplane tow path between Plant 2 and King County International Airport. Soil sample locations in OA 18 exceed the FMCLs for carcinogenic polycyclic aromatic hydrocarbons (cPAH), naphthalene, cyanide, diesel-range petroleum hydrocarbons (DRPH), and MoRPH between 1 and 7 feet bgs within an area approximately 200 feet long by 80 feet wide. Groundwater exceedance areas within RA 6 are well delineated, stable or shrinking relative to historical conditions demonstrating containment, and are located far upgradient from the POC.

Alternative 1: Corrective Action Not Required (with Controls) – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because impacted soil and groundwater is contained beneath pavement. The pavement prevents collection and infiltration of stormwater run-on, provides a barrier against direct contact with any waste or affected soil, and prevents infiltration of precipitation and off-site migration of COCs in groundwater, stormwater runoff, or airborne dust.

- Attain FMCLs – Alternative 1 meets this standard because it does not do anything to shorten the time frame to attaining cleanup standards through natural attenuation. Cleanup standards might not be attained in a reasonable time frame or even in the foreseeable future for some constituents.
- Control the Source of the Releases – Alternative 1 meets this standard because impacted soil is partially contained beneath the OA 18 paved parking area. Hazardous waste is not generated, treated, or stored in this area.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it is not effective at attaining cleanup standards. The rating would be a 1 but the limited attenuation that occurs under natural conditions is considered to be reliable because it occurs without the need for outside input and effort.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because it does nothing to reduce the toxicity of the contaminants. In addition, naturally-occurring attenuation will reduce the volume and concentrations of organic contaminants, although it will likely be a slow process.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is no short-term risk to human health or the environment under this remedial alternative.
- Implementability – Alternative 1 rates high (5) because this alternative is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost Effectiveness – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 1. The estimated cost for Alternative 1 is approximately $48,000 over five years for shoreline well monitoring and reporting.
- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative 2: Source Excavation to FMCLs – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2 meets this standard because impacted soil will be removed and transported off-site for landfill disposal. The potential for site workers to be exposed to contaminants will be eliminated.
- Attain FMCLs – Alternative 2 meets this standard because excavation effectively removes the impacted soil within a reasonable time frame.
- Control the Source of the Releases – Alternative 2 meets this standard because the impacted soil will be removed. Hazardous waste is not generated, treated, or stored in this area.

- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2 meets this standard because excavation and disposal will be conducted in accordance with Washington State dangerous waste regulations and MTCA. Waste management standards including LDR will be met and appropriate disposal facilities will be used, dependent on the waste designation (hazardous, dangerous, or non-hazardous). Excavated soil generated by Alternative 2 would likely be disposed of at a RCRA Subtitle D landfill.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2 rates high (5) because excavation will effectively remove soil contamination exceeding proposed industrial soil FMCLs. Asphalt pavement provides long-term effectiveness by decreasing the migration of COCs in vadose-zone soils by minimizing stormwater infiltration. Long-term monitoring requirements will be reduced by removing the contaminants from the site. Asphalt pavement deterioration over time will be addressed by routine inspection and maintenance for a period of time determined in the Statement of Basis (SOB).
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2 rates medium (3) because it does not reduce the toxicity of the contaminants; however, excavating all impacted soil eliminates toxicity or mobility of waste remaining on site. The mobility of contaminants in excavated soil will be significantly limited by internment in a RCRA Subtitle D landfill. However, the excavated vadose-zone source material will not undergo remediation to reduce its toxicity or volume.
- Short-term Effectiveness – Alternative 2 rates medium (3) because it creates the potential for human exposure to affected soil during excavation, transport, or disposal.
- Implementability – Alternative 2 rates medium high (4) because excavation and disposal are immediately implementable with standard construction equipment; engineering and institutional controls are easily maintained.
- Cost Effectiveness – Alternative 2 rates medium (3) because it is a reasonable cost alternative. Cost to implement this alternative is approximately $1,123,000.
- Restoration Time Frame – Alternative 2 rates high (5) because excavation and off-site disposal has been demonstrated at Plant 2 to effectively remediate soil within a reasonable time frame.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

The potential for groundwater treatment technology has been retained for the organic constituents represented by exceedance area cVOC-7. This exceedance area is the EMF Plume, which is well delineated and is undergoing corrective measures under a separate program administered by USEPA.

Continued performance of ERD in the EMF Plume is expected to achieve FMCLs for the cVOC-7 exceedance areas in RA 6; however, there might be some POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

3.7 RA 7: Unpaved Shoreline Area Remedial Alternative Evaluation

Impacted soil in the south unpaved shoreline area was excavated during the 2010-2012 Plant 2 Demolition/Redevelopment project for construction of the new South Plant 2 stormwater system and in association with Southwest Bank Corrective Measure. Impacted soil in the north unpaved shoreline area was excavated in association with the North Stormwater Area Retrofit. One isolated sample location remains where soil concentrations exceed FMCLs for TCE and petroleum hydrocarbons. Groundwater with concentrations of cVOCs, metals, MoRPH, PCBs, and bis(2-ethylhexyl)phthalate (BEHP) greater than their respective FMCLs are located with the unpaved shoreline area.

Alternative 1: Corrective Action Not Required (with Controls) – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because impacted soil is limited to a single location at 11 feet bgs and groundwater areas are well delineated, are stable or shrinking relative to historical conditions demonstrating containment, and are located far upgradient from the POC.
- Attain FMCLs – Alternative 1 meets this standard because it does not do anything to shorten the time frame to attaining cleanup standards through natural attenuation. Cleanup standards might not be attained in a reasonable time frame or even in the foreseeable future for some constituents.
- Control the Source of the Releases – Alternative 1 meets this standard because impacted soil is limited to a single location and is not migrating, and groundwater exceedance areas are stable or shrinking. Hazardous waste is not generated, treated, or stored in this area.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it is not effective at attaining cleanup standards. The rating would be a 1 but the limited attenuation that occurs under natural conditions is considered to be reliable because it occurs without the need for outside input and effort.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because it does nothing to reduce the toxicity of the contaminants. In addition, naturally-occurring attenuation will reduce the volume and concentrations of organic contaminants, although it will likely be a slow process.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is no short-term risk to human health or the environment under this remedial alternative.

- Implementability – Alternative 1 rates high (5) because it is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost Effectiveness – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 1. Cost to implement this alternative is approximately $48,000.
- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative 2: Bioventing to FMCLs – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2 meets this standard because impacted soil will be treated by bioventing to achieve proposed shoreline soil FMCLs.
- Attain FMCLs – Alternative 2 meets this standard because bioventing would comply with the cleanup standards by treating the soil to achieve proposed shoreline soil FMCLs.
- Control the Source of the Releases – Alternative 2 meets this standard because bioventing will treat impacted soil. Hazardous waste is not generated, treated, or stored in this area.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2 meets this standard because bioventing would be conducted in accordance with Washington State dangerous waste regulations, MTCA, and Puget Sound Clean Air Agency requirements.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2 rates medium high (4) because bioventing will effectively treat soil contamination exceeding proposed shoreline soil FMCLs.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2 rates medium high (4) because bioventing effectively provides permanent reduction in toxicity, mobility, and volume of soil containing, DRPH, MoRPH, and gasoline-range petroleum hydrocarbons (GRPH).
- Short-term Effectiveness – Alternative 2 rates medium high (4) because this bioventing poses low short-term risks to the community during implementation. Risks to workers during implementation will be managed through standard engineering and safety controls. Short-term risks to the environment during implementation would be managed through engineering controls, best management practices (BMPs), and other measures to ensure compliance.
- Implementability – Alternative 2 rates medium high (4) because bioventing can be reliably implemented and would require design, permitting, construction, and implementation of the bioventing system.

- Cost Effectiveness – Alternative 2 rates medium high (4) because it is a reasonable cost alternative for removing cVOCs and fuels from soil. This alternative does not require expensive equipment and operation and maintenance costs are low. Costs to implement this alternative are approximately $91,000.
- Restoration Time Frame – Alternative 2 rates medium high (4) because bioventing has been demonstrated at Plant 2 to significantly reduce cVOC and TPH concentrations within a reasonable time frame.

Alternative 3: Source Excavation– Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 3 meets this standard because impacted soil will be removed and transported off-site for landfill disposal. The potential for site workers to be exposed to contaminants will be eliminated.
- Attain FMCLs – Alternative 3 meets this standard because excavation effectively removes the impacted soil within a reasonable time frame.
- Control the Source of the Releases – Alternative 3 meets this standard because the impacted soil will be removed. Hazardous waste is not generated, treated, or stored in this area.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 3 meets this standard because excavation and disposal will be conducted in accordance with Washington State dangerous waste regulations and MTCA. Excavated soil generated by Alternative 3 would likely be disposed of at a RCRA Subtitle D landfill.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 3 rates high (5) because excavation will effectively remove soil contamination exceeding proposed shoreline soil FMCLs. Asphalt pavement provides long-term effectiveness by decreasing the migration of COCs in vadose-zone soils by minimizing stormwater infiltration. Long-term monitoring requirements will be reduced by removing the contaminants from the site. Asphalt pavement deterioration over time will be addressed by routine inspection and maintenance for a period of time determined in the SOB.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 3 rates medium low (2) because it does not reduce the toxicity of the contaminants; however, excavating all impacted soil eliminates toxicity or mobility of waste remaining on site. The mobility of contaminants in excavated soil will be significantly limited by internment in a RCRA Subtitle D landfill. However, the excavated vadose-zone source material will not undergo remediation to reduce its toxicity or volume.
- Short-term Effectiveness – Alternative 3 rates medium (3) because it creates the potential for human exposure to affected soil during excavation, transport, or disposal.
- Implementability – Alternative 3 rates medium low (2) because excavation and disposal are immediately implementable with standard construction equipment and engineering and institutional controls are easily maintained.

- Cost Effectiveness – Alternative 3 rates medium low (2) because it is a reasonable cost alternative. Costs to implement this alternative are approximately $101,000.
- Restoration Time Frame – Alternative 2 rates medium high (4) because excavation and off-site disposal has been demonstrated at Plant 2 to effectively remediate soil within a reasonable time frame.

Alternative AM-1: Adaptive Management for Inorganics in Groundwater – Description and Scope of Work

Boeing anticipates that implementation of remedial actions for TCE, GRPH, DRPH, and MoRPH exceedance areas will reduce inorganic COC concentrations in RA 7 and that property boundary monitoring results will demonstrate that inorganic COCs in RA 7 do not impact groundwater at concentrations greater than FMCLs at the POC.

Where Adaptive Management for inorganics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective action technology determinations. The Adaptive Management process for inorganic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-12.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

Implementation of the proposed corrective measures is expected to achieve FMCLs for RA 7 exceedance areas; however, there might be some POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

Alternative AM-3: Adaptive Management for PCBs in Groundwater – Description and Scope of Work

The potential for groundwater treatment technology and additional groundwater monitoring has been retained for PCBs, which have been analyzed for four semiannual events in samples from shoreline monitoring wells PL2-617A, PL2-618A, PL2-619A, and PL2-620A with no PCB detections using the current analytical method. Boeing may temporarily discontinue analyzing for PCB Aroclors in groundwater at those locations.

In the future, Boeing will conduct PCB analysis in groundwater using a high-sensitivity analytical method (e.g., USEPA Method 1668) to achieve a reporting limit equal to or lower than the WQS, which is the TMCL for PCBs. At this time, USEPA may require sampling for PCBs at wells where PCB sampling had previously been discontinued. Boeing will work with USEPA through an Adaptive Management process to apply the high-sensitivity PCB analysis method for this ongoing groundwater monitoring, which may include specific requirements for data collection and analysis. As new data collected under this method become available, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and response.

3.8 RA 8: Paved Industrial Area Remedial Alternative Evaluation

As identified in Section 3.0, numerous activities have been conducted in the paved industrial area that involved soil excavations removing impacted soil. These activities included construction projects conducted in support of facilities/equipment construction, building construction, stormwater revisions, and repairs and demolition. There are eight isolated soil sample locations with concentrations of arsenic, chromium, cyanide, cPAH, and MoRPH exceeding FMCLs in the paved industrial area. Groundwater exceedance areas are generally small, well-delineated, stable or shrinking and do not reach the POC.

Alternative 1: Corrective Action Not Required (with Controls) – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because impacted soil is limited to eight discrete locations and groundwater areas are generally small and isolated and are located far upgradient from the POC.
- Attain FMCLs – Alternative 1 meets this standard because it does not do anything to shorten the time frame to attaining cleanup standards through natural attenuation. Cleanup standards might not be attained in a reasonable time frame or even in the foreseeable future for some constituents.
- Control the Source of the Releases – Alternative 1 meets this standard because impacted soil is limited to eight discrete locations and is not migrating and groundwater exceedance areas are stable or shrinking. Hazardous waste is not generated, treated, or stored in this area.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it is not effective at attaining cleanup standards. The rating would be a 1 but the limited attenuation that occurs under natural conditions is considered to be reliable because it occurs without the need for outside input and effort.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because it does nothing to reduce the toxicity of the contaminants. In addition, naturally-occurring attenuation will reduce the volume and concentrations of organic contaminants, although it will likely be a slow process.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is no short-term risk to human health or the environment under this remedial alternative.
- Implementability – Alternative 1 rates high (5) because this alternative is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost Effectiveness – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 8. The cost to implement this remedial action would likely be provided by other RA monitoring budgets.

- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative 2: Source Excavation to FMCLs – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 2 meets this standard because impacted soil will be removed and transported off-site for landfill disposal. The potential for site workers to be exposed to contaminants will be eliminated.
- Attain FMCLs – Alternative 2 meets this standard because excavation effectively removes the impacted soil within a reasonable time frame.
- Control the Source of the Releases – Alternative 2 meets this standard because the impacted soil will be removed. Hazardous waste is not generated, treated, or stored in this area.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 2 meets this standard because excavation and disposal will be conducted in accordance with Washington State dangerous waste regulations and MTCA. Waste management standards including LDR will be met and appropriate disposal facilities will be used, dependent on the waste designation (hazardous, dangerous, or non-hazardous). Excavated soil generated by Alternative 2 would likely be disposed of at a RCRA Subtitle D landfill under a CID from Ecology, which is a type of waiver.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 2 rates high (5) because excavation will effectively remove soil contamination exceeding proposed industrial soil FMCLs. Asphalt pavement provides long-term effectiveness by decreasing the migration of COCs in vadose-zone soils by minimizing stormwater infiltration. Long-term monitoring requirements will be reduced by removing the contaminants from the site. Asphalt pavement deterioration over time will be addressed by routine inspection and maintenance for a period of time determined in the SOB.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 2 rates medium (3) because this alternative does not reduce the toxicity of the contaminants; however, excavating all impacted soil eliminates toxicity or mobility of waste remaining on site. The mobility of contaminants in excavated soil will be significantly limited by internment in a RCRA Subtitle D landfill. However, the excavated vadose-zone source material will not undergo remediation to reduce its toxicity or volume.
- Short-term Effectiveness – Alternative 2 rates medium high (4) because this alternative creates the potential for human exposure to affected soil during excavation, transport, or disposal.
- Implementability – Alternative 2 rates medium high (4) because excavation and disposal are immediately implementable with standard construction equipment and engineering and institutional controls are easily maintained.

- Cost Effectiveness – Alternative 2 rates medium high (4) because it is a reasonable cost alternative. Costs to implement this alternative are approximately $240,000.
- Restoration Time Frame – Alternative 2 rates medium high (4) because excavation and off-site disposal has been demonstrated at Plant 2 to effectively remediate soil within a reasonable time frame.

Alternative AM-1: Adaptive Management for Inorganics in Groundwater – Description and Scope of Work

Boeing anticipates that implementation of remedial actions for arsenic, cPAH, and MoRPH exceedance areas will reduce inorganic COC concentrations in RA 8 and that property boundary monitoring results will demonstrate that inorganic COCs in RA 8 do not impact groundwater at concentrations greater than FMCLs at the POC.

Where Adaptive Management for inorganics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective action technology determinations. The Adaptive Management process for inorganic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-12.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

Implementation of the proposed corrective measures is expected to achieve FMCLs for RA 8 exceedance areas; however, there might be some POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

Alternative AM-3: Adaptive Management for PCBs in Groundwater – Description and Scope of Work

The potential for groundwater treatment technology and additional groundwater monitoring has been retained for PCBs, which have been analyzed for four semiannual events in samples from shoreline monitoring wells PL2-617A, PL2-618A, PL2-619A, and PL2-620A, which are located in RA 7 but are downgradient of tunnels backfilled with crushed concrete containing detections of PCBs in RA 8. PCBs were not detected, using the current analytical method, during the four sampling events completed at these wells. Boeing may temporarily discontinue analyzing for PCB Aroclors in groundwater at those locations.

In the future, Boeing will conduct PCB analysis in groundwater using a high-sensitivity analytical method (e.g., USEPA Method 1668) to achieve a reporting limit equal to or lower than the WQS, which is the TMCL for PCBs. At this time, USEPA may require sampling for PCBs at wells where PCB sampling had previously been discontinued. Boeing will work with USEPA through an Adaptive Management process to apply the high-sensitivity PCB analysis method for this ongoing groundwater monitoring, which may include specific requirements for data collection and analysis.

As new data collected under this method become available, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and response.

3.9 RA 9: OA 11 Area Remedial Alternative Evaluation

In 2016, a corrective measure for OA-11 was performed as an IM jointly with the TSCA program under a RBDA. The IM consisted of excavation of soil primarily impacted with PCBs, TPH; and low levels of VOCs (i.e., TCE and vinyl chloride) were also concurrently removed. The excavation was completed between September 6 and 20, 2016. A total of approximately 50 cy of Subtitle C soil and pipe debris totaling 124 tons, and approximately 650 cy of Subtitle D soil totaling 1,020 tons were excavated as part of the IM. In addition, a total of approximately 78 tons of debris (including the former transformer pad, inactive stormwater features, and other miscellaneous debris) were removed and transported to a Subtitle D landfill for disposal.

Alternative 1: Corrective Action Not Required (with Controls and Monitoring) – Rationale for RCRA Alternative Evaluation Standards Ratings

RCRA Standards:

- Protect Human Health and the Environment – Alternative 1 meets this standard because impacted soil was removed by excavation as part of the OA 11 IM. Groundwater areas do not reach the POC and are small, well delineated, and stable or shrinking.
- Attain FMCLs – Alternative 1 meets this standard because it does not do anything to shorten the time frame to attaining cleanup standards through natural attenuation. Cleanup standards might not be attained in a reasonable time frame or even in the foreseeable future for some constituents.
- Control the Source of the Releases – Alternative 1 meets this standard because impacted soil has been removed and groundwater exceedance areas are stable or shrinking. Hazardous waste is not generated, treated, or stored in this area.
- Comply with Applicable Standards for Management of Waste (with or without waivers) – Alternative 1 meets this standard because no waste is generated.

Other Factors:

- Long-term Reliability and Effectiveness – Alternative 1 rates medium low (2) because it is not effective at attaining cleanup standards. The rating would be a 1 but the limited attenuation that occurs under natural conditions is considered to be reliable because it occurs without the need for outside input and effort.
- Reduction in Toxicity, Mobility, or Volume of Waste – Alternative 1 rates medium low (2) because it does nothing to reduce the toxicity of the contaminants. In addition, naturally-occurring attenuation will reduce the volume and concentrations of organic contaminants, although it will likely be a slow process.
- Short-term Effectiveness – Alternative 1 rates high (5) because there is no short-term risk to human health or the environment under this remedial alternative.

- Implementability – Alternative 1 rates high (5) because this alternative is immediately implementable with minor effort required to maintain engineering and institutional controls.
- Cost Effectiveness – Alternative 1 rates high (5) because it is the lowest cost alternative for RA 9. The cost to implement this remedial action would likely be provided by other RA monitoring budgets.
- Restoration Time Frame – Alternative 1 rates medium low (2) because naturally occurring attenuation will reduce the volume and concentrations of organic contaminants; however, without additional active remediation efforts it will probably require a long restoration time frame.

Alternative AM-1: Adaptive Management for Inorganics in Groundwater – Description and Scope of Work

Boeing anticipates that the completed corrective action in RA 9 will reduce inorganic COC concentrations in and that monitoring results will demonstrate that inorganic COCs in RA 9 do not impact groundwater at concentrations greater than FMCLs at the POC.

Where Adaptive Management for inorganics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective action technology determinations. The Adaptive Management process for inorganic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-12.

Alternative AM-2: Adaptive Management for Organics in Groundwater – Description and Scope of Work

Implementation of the proposed corrective measures is expected to achieve FMCLs for RA 9 exceedance areas; however, there might be some POC locations that do not achieve or consistently maintain FMCLs over time for organic COCs. A suitable corrective action technology will only be considered if groundwater monitoring data indicate that further consideration of corrective action for one or more of these exceedance areas is warranted.

Where Adaptive Management for organics is warranted, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and corrective technology determinations. The Adaptive Management process for organic COCs is presented in Section 6.3.8 and is shown graphically on Figure 6-13.

Alternative AM-3: Adaptive Management for PCBs in Groundwater – Description and Scope of Work

The potential for groundwater treatment technology and additional groundwater monitoring has been retained for PCBs represented by exceedance area PCB-1. PCB-impacted soils have been removed from this area and downgradient groundwater will be monitored at PL2-007AR and proposed well PL2-613A (Location A). Boeing will continue to analyze for PCB Aroclors in groundwater at these locations using USEPA Method 8082A with an MDL of approximately 0.01 µg/L and will compare those data to PQL of 0.1 µg/L. After completion of 8 semiannual monitoring events, Boeing may request an Adaptive Management response to the data collected from these wells.

In the future, Boeing will conduct PCB analysis in groundwater using a high-sensitivity analytical method (e.g., USEPA Method 1668) to achieve a reporting limit equal to or lower than the WQS,

which is the TMCL for PCBs. At this time, USEPA may require sampling for PCBs at wells where PCB sampling had previously been discontinued. Boeing will work with USEPA through an Adaptive Management process to apply the high-sensitivity PCB analysis method for this ongoing groundwater monitoring, which may include specific requirements for data collection and analysis. As new data collected under this method become available, Boeing will work in coordination with and seek approval from USEPA to develop and implement an appropriate strategy for data evaluation and response.